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MICROMECHANICAL COMPONENT AND CORRESPONDING MANUFACTURING METHOD

Background Information

The present invention relates to a micromechanical component including a substrate, a micromechanical functional plane provided on the substrate, a covering plane provided on the micromechanical functional plane, and a printed circuit trace plane provided on the covering plane. The present invention also relates to a corresponding manufacturing method.

Micromechanical function will be understood as an arbitrary active function, for example a sensor function, or passive function, for example a printed circuit trace function.

Although applicable to arbitrary micromechanical components and structure, in particular to sensors and actuators, the present invention and its underlying problem will be explained with reference to a micromechanical component, for example an acceleration sensor, which is manufacturable in the technology of silicon surface micromachining.

Generally known are monolithically integrated, surface-micromachined inertial sensors whose movable structures are affixed to the chip in an unprotected manner (analog devices). Because of this, an increased expenditure of time and energy during handling and packaging ensues.

This problem can be avoided using a sensor having the evaluation circuit on a separate chip; in this context, for example, the surface-micromachined structures are covered by a second cap wafer. This type of packaging creates a high portion of the cost of a surface-micromachined acceleration sensor. This cost results from the large surface required for

the sealing surface between the cap wafer and the sensor wafer and because of the complex patterning (2-3 masks, bulk micromachining) of the cap wafer.

The evaluation circuit is implemented on a second chip and connected to the sensor element via wire bottom. This, in turn, creates the necessity for the sensor elements to be sized such that the parasitic effects developing due to the parasites in the lead wires and bonding wires are negligible, that they no longer have any dominant influence on the sensor function. In addition, flip-chips techniques have to be ruled out because of parasitic effects.

Such sensors could make do with considerably less surface for the micromechanics if the evaluation circuit were situated on the same Si chip and the sensitive electrodes could be connected with only low parasities.

German Patent Application DE 195 37 814 A1 describes the structure of a functional layer system and a method for the hermetically packaging of surface-micromachined sensors. Explained in this context is the manufacture of the sensor structure using known technological methods. The mentioned hermetical packaging is effected using a separate cap wafer which is made of silicon and patterned using complex patterning processes such as KHO etching. The cap wafer is affixed to the substrate featuring the sensor (sensor wafer) using a glass solder (seal glass). For this purpose, a broad bonding frame is required around each sensor chip to ensure sufficient adhesion and tightness of the cap. This considerably reduces the number of sensor chips per sensor wafer. Due to large space required and the complex manufacture of the cap wafer considerable costs are attributable to the sensor packaging.

German Patent Application DE 43 41 271 A1 discloses a micromechanical acceleration sensor whose components are

composed partly of monocrystalline material and partly of polycrystalline material. For manufacturing this known micromechanical acceleration sensor, an epitaxial reactor is used. A starting layer made of LPCVD polysilicon is used for determining the regions where polycrystalline silicon is intended to grow during the epitaxial process.

Advantages of the Invention

The micromechanical component according to the present invention having the features of Claim 1 and the manufacturing method according to Claim 9 have the following advantages. It is possible for the evaluation circuit and the sensor element to be monolithically integrated on one chip. Error-prone complex bonding wires between the sensor element and the evaluation circuit can be omitted. The size of the sensing elements can be reduced since less parasitic effects occur in the bonding. Only one chip has to be mounted. The process is based on the surface-micromachining process known from document P4318466.9 which yields epitaxial polysilicon having a thickness of at least 10 μm. A simplification of the surface-micromachining process ensues because the structures can be bonded from above. The buried polysilicon can be omitted.

The integration of the component is independent of the process of the evaluation circuit to the greatest possible extent as a result of which an adaptation to new IC processes is simplified. Depending on the sensor principle, the component can be reduced to the size of the bonding pads heretofore required on the IC for bonding as a result of which the cost is not increased due to additional surface.

According to the present invention, the sensor chip can be connected using the so-called "flip-chip method", that is upside down with eutectic or gold bumps instead of using bonding wires since the parasitic influences are strongly

reduced in comparison with the two-chip solution. Using this technique, it is also possible to produce sensors with CSP (chip scale package) whose package is no more than 20% larger than the chip. A CPS-packaged chip can be premeasured and trimmed prior to assembly.

The core of the present invention is the combination of the single-crystalline and polycrystalline growth during the deposition of the covering layer in the epitaxial reactor. In the process, single-crystalline silicon requires a single-crystalline surface as a starting layer, polycrystalline silicon requires a polycrystalline starting layer which is preferably deposited using LPCVD.

Advantageous refinements and improvements of the respective objective of the present invention can be found in the subclaims.

According to a preferred refinement, a first layer featuring the micromechanical functional plane has a monocrystalline region which is epitaxially grown on the underlying monocrystalline region as well as a polycrystalline region which is epitaxially grown on the underlying polycrystalline starting layer at the same time. Thus, the same epitaxial step is used twice in two different planes.

According to a further preferred refinement, a first layer featuring the micromechanical functional plane has an SOI-type monocrystalline region formed above an insulator layer with the substrate. This has the advantage that the buried polysilicon layer can be omitted and that one epitaxial step is dropped. Preferably used as silicon is a single-crystalline, high-doped base material which is free of mechanical stress.

According to another preferred refinement, the monocrystalline region includes a second layer which is deposited on the first

layer and which features one or a plurality of integrated circuit elements of an evaluation circuit or wiring elements. In this manner, a so-called "monolithically integrated one-chip solution" can be attained.

According to a further preferred embodiment, the polycrystalline region of the micromechanical functional plane features a movable sensor structure.

According to a further preferred refinement, the micromechanical functional plane features a buried polysilicon layer underneath the movable sensor structure.

According to another preferred refinement, one or a plurality of flip-chip connection elements, preferably gold bumps, are provided in the printed circuit trace plane. This is a rugged bonding type which is made possible by the substantially planar surface.

According to a further preferred embodiment, the component can be manufactured by silicon surface micromachining.

Drawings

Exemplary embodiments of the present invention are depicted in the drawing and will be explained in greater detail in the following description.

Figure 1 shows a schematic cross-sectional view of a micromechanical component according to a first embodiment of the present invention,

Figures 2a,b depict a schematic cross-sectional view of a the manufacturing steps of the micromechanical component according to Figure 1; and

Figure 3 shows a schematic cross-sectional view of a micromechanical component according to a second embodiment of the present invention,

Description of the Exemplary Embodiments

In the Figures, identical or functionally identical components are denoted by the same reference symbols.

Figure 1 is a schematic cross-sectional view of a micromechanical component according to a first embodiment of the present invention.

In Figure 1, 1 denotes a silicon substrate wafer, 2 a lower oxide, 3 buried polysilicon , 4 a contact hole in sacrificial oxide 5, 5 a sacrificial oxide , 6 a first starting polysilicon, 7 a first single-crystalline silicon of epitaxy, 8 a first epitaxial polysilicon, 9 an insulating trench, 10 a movable sensor structure, 11 a first refill oxide, 12 a contact hole in refill oxide 11, 13 a second starting polysilicon, 14 a second single-crystalline silicon of epitaxy, 15 a second epitaxial polysilicon, 16 an electrical and/or mechanical connecting element between the first and the second epitaxial polysilicon, 17 a trench, 18 a second refill oxide, 19 an oxide for insulating the printed circuit traces, 20 a cross connection, 21 a printed circuit trace, 22 a contact hole in printed circuit trace 21 and in refill oxide 18 and 23 an electronic component of the evaluation circuit.

100 denotes a micromechanical functional plane featuring movable sensor structure 10, here an acceleration sensor, 200 a covering plane for hermetically sealing movable sensor structure 10, and 300 a printed circuit trace plane.

In this first embodiment, which can be manufactured by silicon surface micromachining which is known per se, covering plane 200, on one hand, features monocrystalline region 14 which is

epitaxially grown on underlying monocrystalline region 7. On the other hand, covering plane 200 features polycrystalline region 15 which is epitaxially grown on underlying polycrystalline starting layer 13 at the same time. In other words, monocrystalline and polycrystalline silicon is grown side by side in one process step.

Monocrystalline region 14 of covering plane 200 contains integrated circuit elements of an evaluation circuit. A CMOS transistor 23 is illustrated as an example.

Analogously, micromechanical functional plane 100 features monocrystalline region 7 which is epitaxially grown on underlying monocrystalline substrate region 1 and polycrystalline region 8 which is epitaxially grown on underlying polycrystalline starting layer 6 at the same time. This process step of simultaneously growing Si in single- and polycrystalline form is carried out both for sensor structure 10 and for covering plane 200.

Micromechanical functional plane 100 features buried polysilicon layer 3 underneath movable sensor structure 10 as a wiring plane.

Figures 2a,b depict a schematic cross-sectional view of a the manufacturing steps of the micromechanical component according to Figure 1.

In general, IC processes require a single-crystalline Si substrate as a starting material for the process. This applies both to processes with analog components requiring an epitaxially deposited single-crystalline Si layer and pure CMOS processes not requiring epitaxy. In this example, therefore, one starts with a single-crystalline Si wafer as substrate 1.

In a first step, an oxidation of substrate 1 is carried out to form lower oxide 2. Subsequently, buried polysilicon 3 is deposited and patterned as a lower printed circuit trace region. In a following step, sacrificial oxide 5 is deposited and patterned. Thereupon, a deposition and patterning of first starting polysilicon 6, in particular a removal of the starting polysilicon and of lower oxide 2 are carried out at locations where single-crystalline silicon (region 7 in Figure 2a) is intended to grow on substrate 1 during the later epitaxy step.

After that, the epitaxy step is carried out in which monocrystalline silicon region 7 is grown together with polycrystalline silicon region 8 of micromechanical functional plane 100. A further step is an optional planarization of the resulting structure to compensate for slight differences in height due to the substructure lying between substrate 1 and polycrystalline silicon region 8.

Then, as illustrated in Figure 2b, a refilling is carried out with refill oxide 11 as well as a patterning of refill oxide 11 to form contact holes 12. Subsequently, second starting polysilicon layer 13 is deposited and patterned together with first refill oxide 11, in particular, second starting polysilicon layer 13 and refill oxide 11 are removed where single-crystalline silicon (region 14 in Figure 2b) is intended to grow on region 7. In a subsequent process step, the second epitaxial process follows in which monocrystalline silicon is deposited in region 14 and polycrystalline silicon is concurrently deposited in region 15. Again, optionally, a planarization of the resulting covering layer is carried out to compensate for the substructure between polysilicon region 8 and polysilicon region 15.

Thereupon, trenches 17 which are used for insulation and as etch holes for removing first refill oxide 11 are formed in second epitaxial polysilicon 15. The etch profile of trenches

17 can be selected in such a manner that they widen downward as indicated in Figure 2b. The upper opening diameter should be selected to be minimal so that the deposition of second refill oxide 18 can be accomplished more quickly and, in fact, without a significant quantity of second refill oxide 18 getting into movable sensor structure 10. Thus, an anisotropic oxide deposition is desired and, to be more precise, only on the surface if possible.

In a subsequent process step, movable sensor structure 10 is etched free by removing lower oxide 2, sacrificial oxide 5 and first refill oxide 11 through etch trenches 17. For better control, it would also be possible to divide the etching free into two steps in that, prior to depositing first refill oxide 11, lower oxides 2 and 5 are removed and first refill oxide 11 is deposited only then. An important advantage of this process lies in that, during sacrificial layer etching which is presently carried out with HF vapor, no electronic circuit or aluminum are present yet which, in the case of back-end processes, can be protected only with great difficulty and effort.

In the next step, second refill oxide 18 is deposited and patterned, a predetermined pressure is adjusted, and a predetermined gas atmosphere is adjusted during the final closing of the hollow spaces by second refill oxide 18, which determines the properties of the enclosed gas consequently, inter alia, the attenuation of mechanical sensor structure 10.

Subsequent to the completion of the micromechanical component, the IC process, for example a CMOS or BiCMOS process, can now be carried out for manufacturing the evaluation circuit in monocrystalline silicon region 14. Thereupon, a deposition and patterning of printed circuit trace plane 300, in particular of oxide 19 and printed circuit trace aluminum 21 take place. To complete the component, usually, the chips are diced and an assembly is carried out as with standard IC components.

Figure 3 is a schematic cross-sectional view of a micromechanical component according to a second embodiment of the present invention.

In Figure 3, in addition to the reference symbols already introduced, 24 denotes an SOI (Silicon on Insulator) layer and 25 an insulator layer. In this second embodiment, thus, substrate 1, insulator layer 25 and monocrystalline silicon layer 24 form an SOI structure which is known per se.

In the so designed component, lower oxide 2, buried polysilicon 3, contact hole 4 in sacrificial oxide 5, sacrificial oxide 5, first starting polysilicon 6, first single-crystalline silicon of epitaxy 7, and first epitaxial polysilicon 8 are omitted.

Consequently, if such an SOI wafer is used as the starting material, then numerous process steps are dropped since then, the mechanically active structure is formed from SOI material 24. In this second embodiment, thus, the entire wiring is transferred into printed circuit trace plane 300.

Although the present invention has been described above in the light of preferred exemplary embodiment, it is not limited thereto but can be modified in many ways.

In particular, it is possible to use arbitrary micromechanical base materials such as germanium and not only the silicon substrate specified by way of example.

Also, it is possible to form arbitrary sensor structures and not only the illustrated acceleration sensor.

Region 15 does not necessarily have to be polycrystalline but can also be recrystallized or the like.